Fortum Oyj

Batcave & Spring – storage solutions for future energy system

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Fortum – For a cleaner world

Megatrends

Climate change and resource efficiency
Urbanisation
Active customers
Digitalisation, new technologies

Mission

We engage our customers and society to drive the change towards a cleaner world. Our role is to accelerate this change by reshaping the energy system, improving resource efficiency and providing smart solutions. This way we deliver excellent shareholder value.

Strategy


Drive productivity and industry transformation


Grow in solar and wind


Create solutions for sustainable cities


Build new energy ventures

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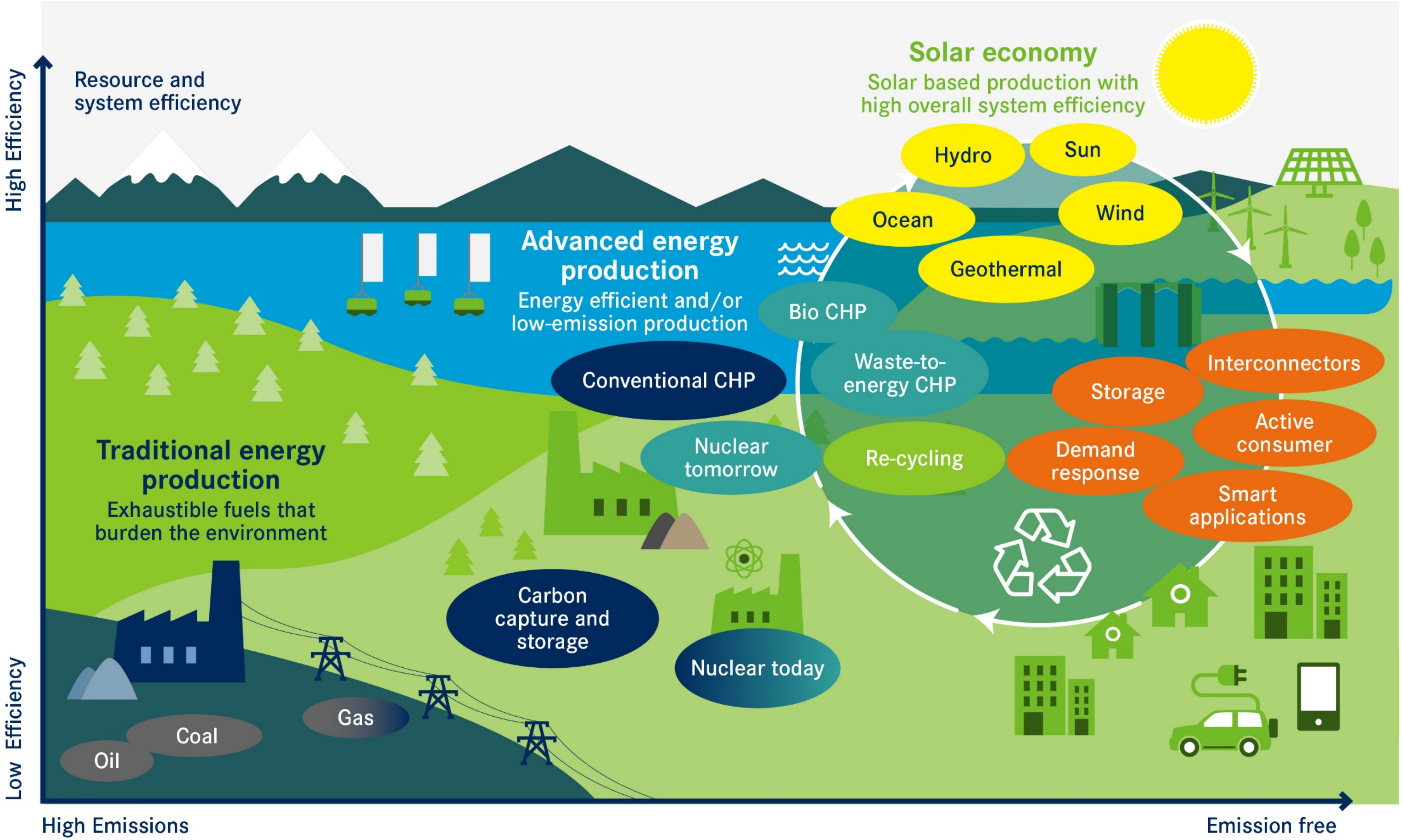
Transition towards Solar Economy is ongoing



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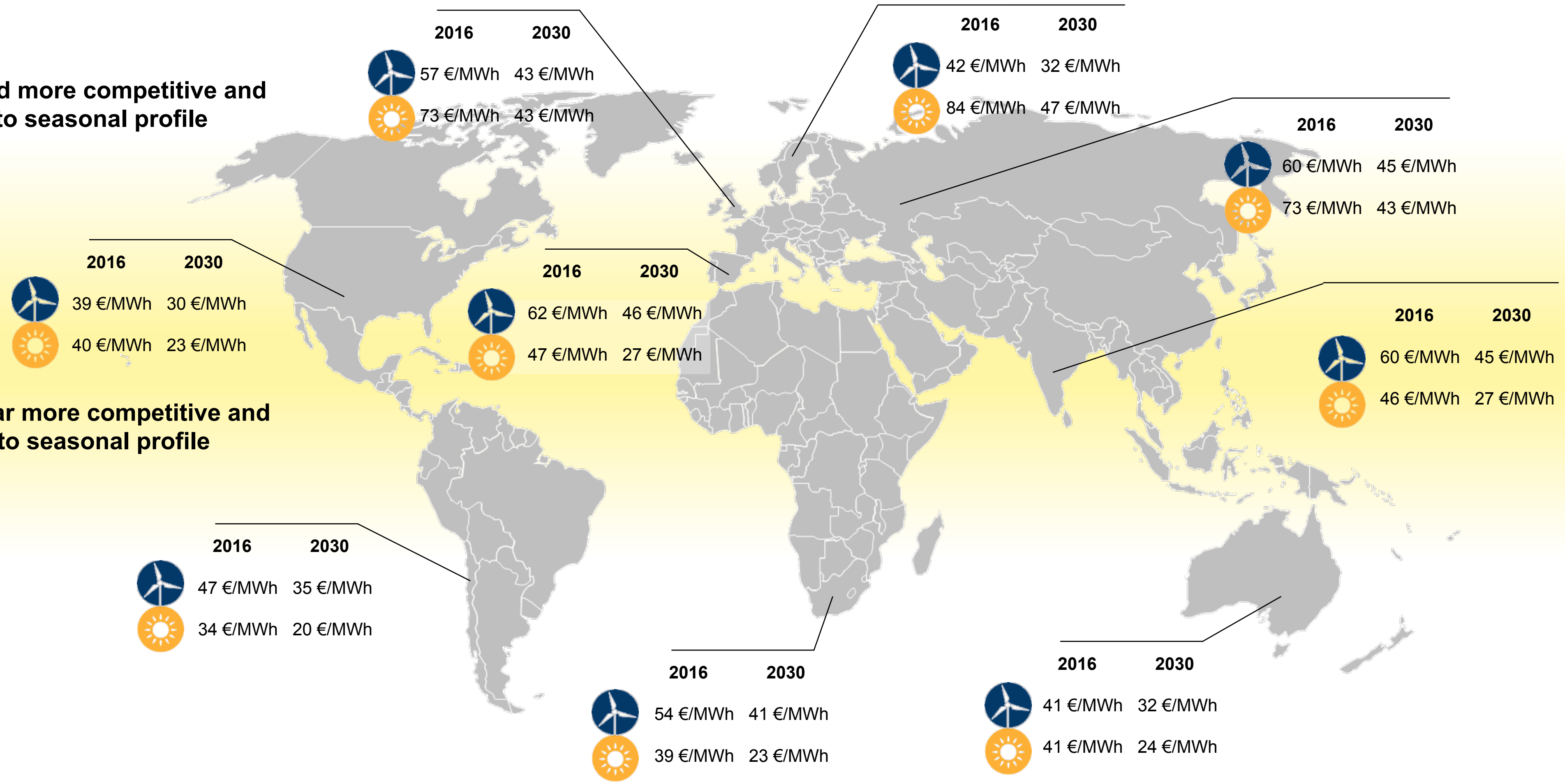
Future energy system changes to:

Security of Supply a limited resource + Energy a non limited resource

World Solar and Wind LCOE's using newest publicly available data

Wind more competitive and fits to seasonal profile

Solar more competitive and fits to seasonal profile



- **Clear seasonality**
- **Wind most competitive**
- **Intermittent power**

- **Low seasonality**
- **PV most competitive**
- **Intermittent power**

NOTE: Solar and wind resources and CAPEX may largely vary by individual projects, even on same region, thus impacting LCOE. Hence, figures are indicative and do not aim to present our geographical preferences for given technologies but rather illustrate progress of wind and solar globally, long-term.

PV LCOE assumptions based on EU PV Technology Platform report and EU PVSEC 2015 paper. Wind CAPEX and OPEX Sweco: Incitamenten för investeringar i kraftproduktion, Capacity factors from BNEF LCOE low case. Indicative wind capacity factor for Russia from IFC Advisory: Services Russia's New Capacity-based Renewable Energy Support Scheme

LCOE assumptions:
- 6% real WACC
- CAPEX, OPEX globally uniform; lifetime solar 30y, wind 25y
- Assumption that capacity factor will increase for solar 7,5% and wind by 15% from 2016 to 2030
- 20% higher CAPEX for the rest of the world compared to low cost Nordic
- Uniform 20% corporate tax assumed

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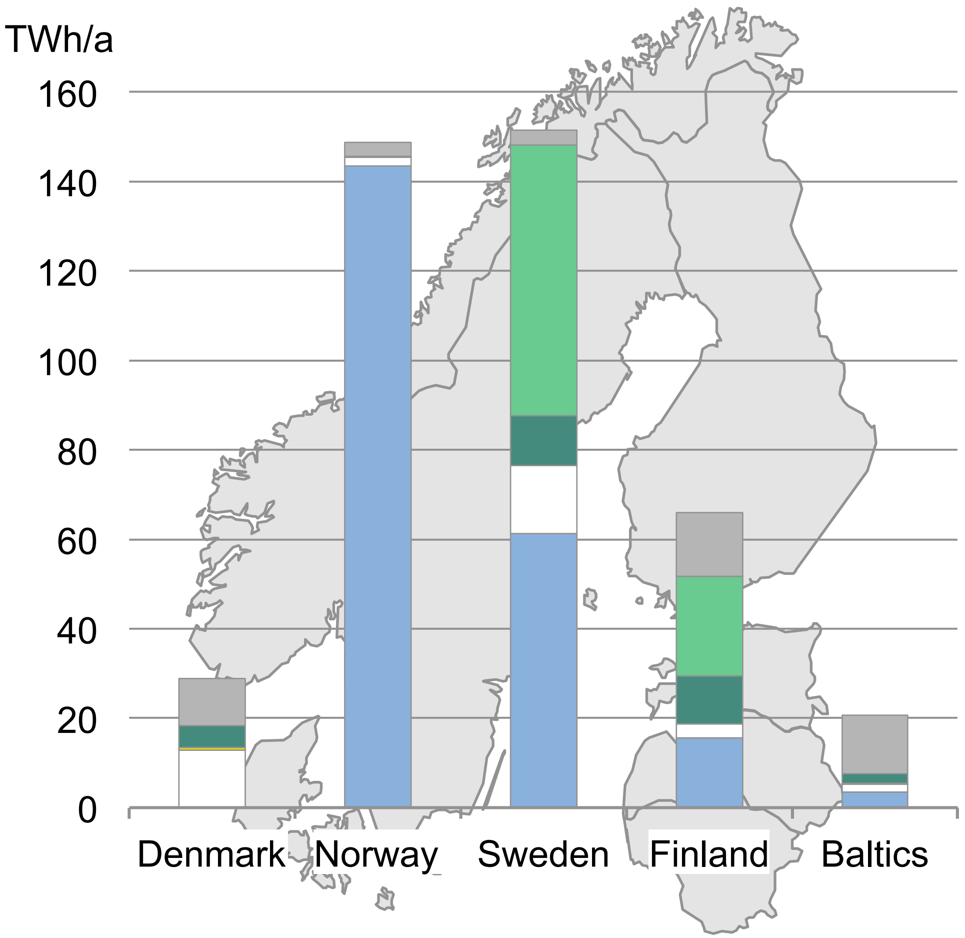
The Nordic power system

Power generation in the Nordic and Baltic countries

– dominated by hydro, but fossil needed



Power generation in 2016	Nordic TWh	Nordic %	Baltics TWh	Baltics %
Fossil fuels	31	8	13	64
Nuclear	83	21	-	-
Biomass, waste	27	7	2	10
Solar	1	0.2	0.1	0.5
Wind	33	8	2	9
Hydro *	220	56	4	17
Total generation	395		21	

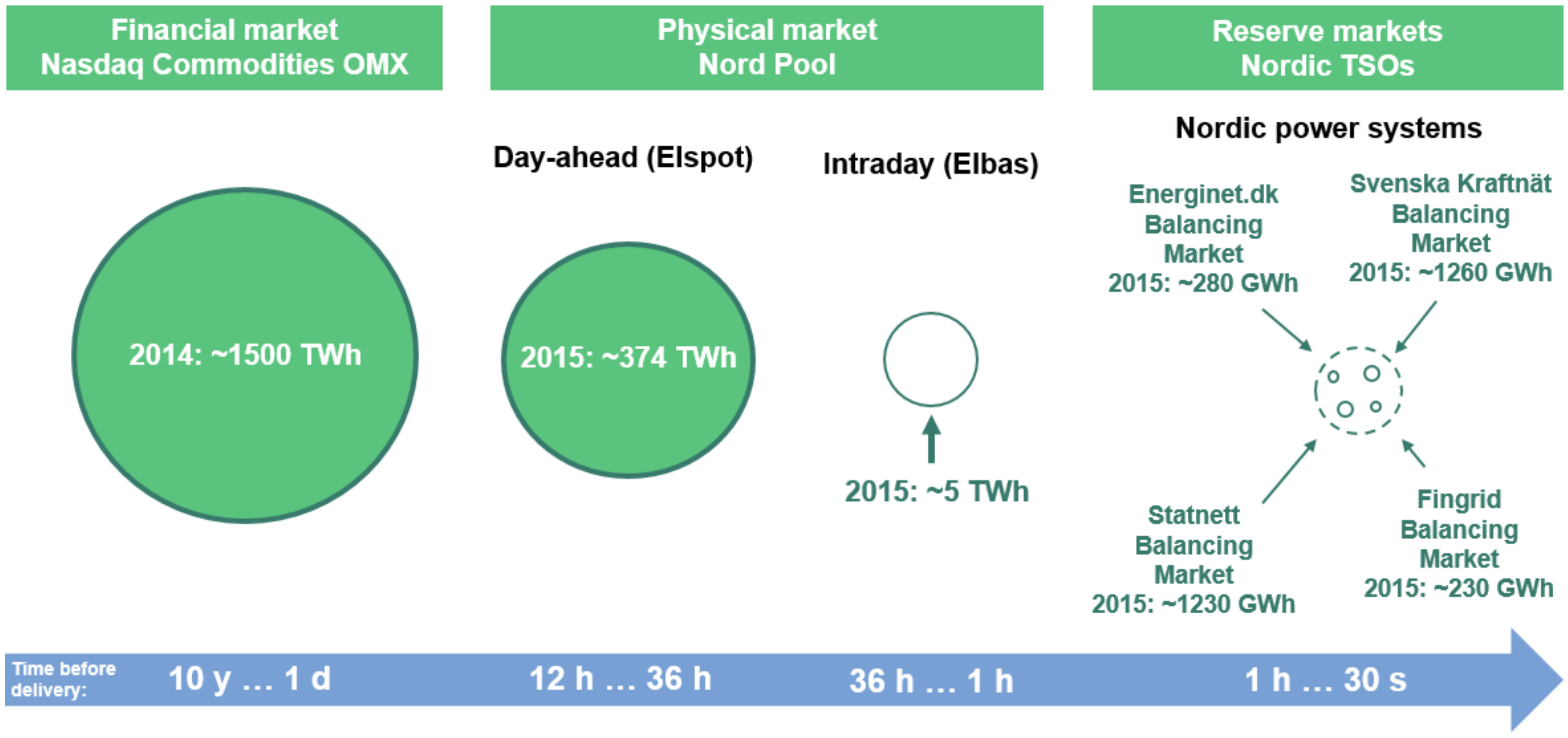
Nordic net export 4 TWh
Baltic net import 7 TWh

Source: ENTSO-E Statistical Factsheet 2016

*) Normal annual Nordic hydro generation 200 TWh, variation +/- 40 TWh.

Electricity market places in the Nordics

- The entire Nordic power exchange is open and neutral market place where the electricity price is determined by rules of supply and demand
- The trading places of Nordic power exchange are divided into three categories: financial, physical and reserve markets



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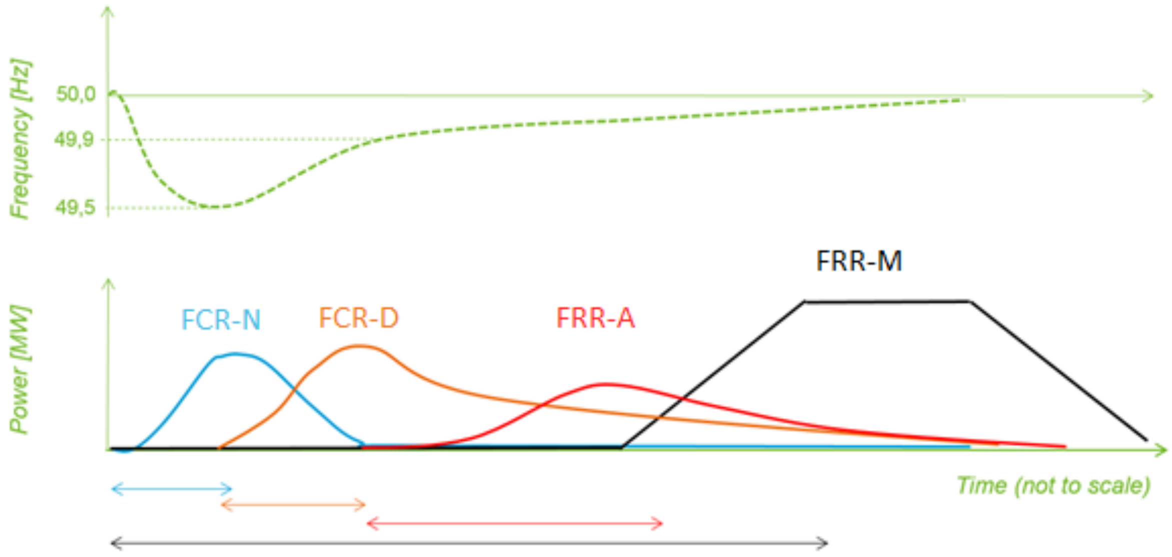
Fingrid's reserve markets

- Because the grid frequency has to be kept at all times at 50 Hz, or in its approximation, the physical markets alone can't regulate the occurring balance alterations sufficiently
  - Thus, reserve markets are designed to balance all the micro-shifts that appear in grid system due to the production and consumption variations
- According to System Operation Agreement the TSOs of each country are obligated to maintain and balance their reserves. In Finland Fingrid operates as the transmission system operator
- The Fingrid's reserve obligations sizes and their activation orders according to frequency drop are listed below

Reserve product	Obligation
Frequency Containment Reserve for Normal operation (FCR-N)	~ 140 MW
Frequency Containment Reserve for Disturbances (FCR-D)	220 - 265 MW
Automatic Frequency Restoration Reserve (FRR-A)	70 MW
Fast Disturbance Reserve (FRR-M)	880 - 1100 MW



Source for reserve markets material: Fingrid

Battery operation in Nordic electricity markets

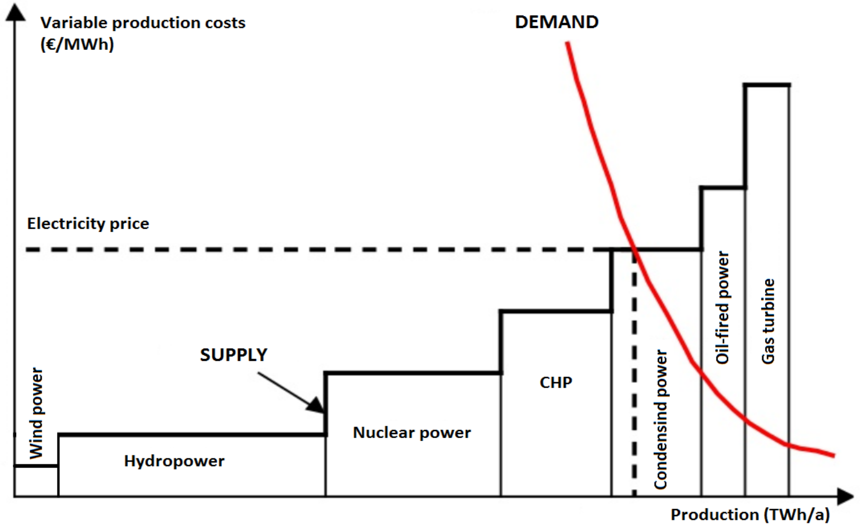
Battery operation in Nordic electricity markets

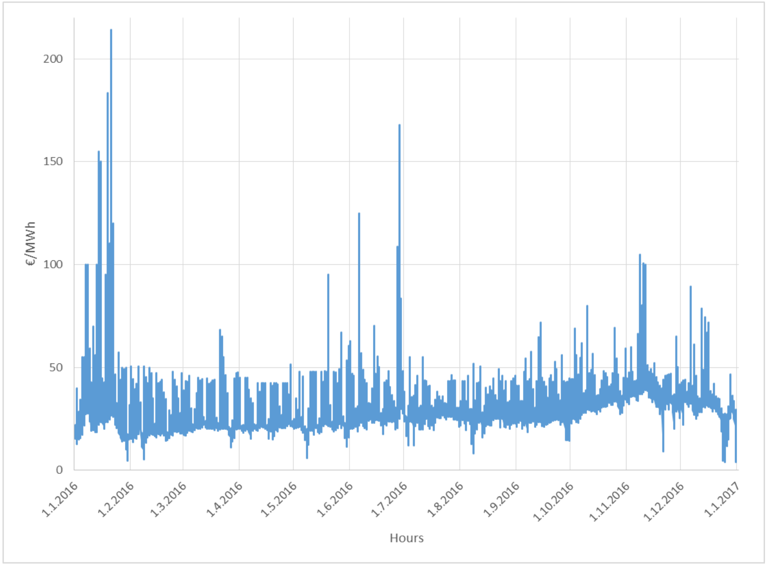
- The benefit of electrochemical batteries is that they
  - can react fast to the requirements of power grid
  - can adapt efficiently to its variations
  - have good efficiency ratios as there is no mechanical movement required
- Nevertheless, batteries are
  - expensive
  - restricted to store huge amounts of energy for longer time periods

With these inputs, in which electricity market place the battery should be operated to take advantage of its best features in order to maximize the profit?

Economic challenges of batteries in physical power markets

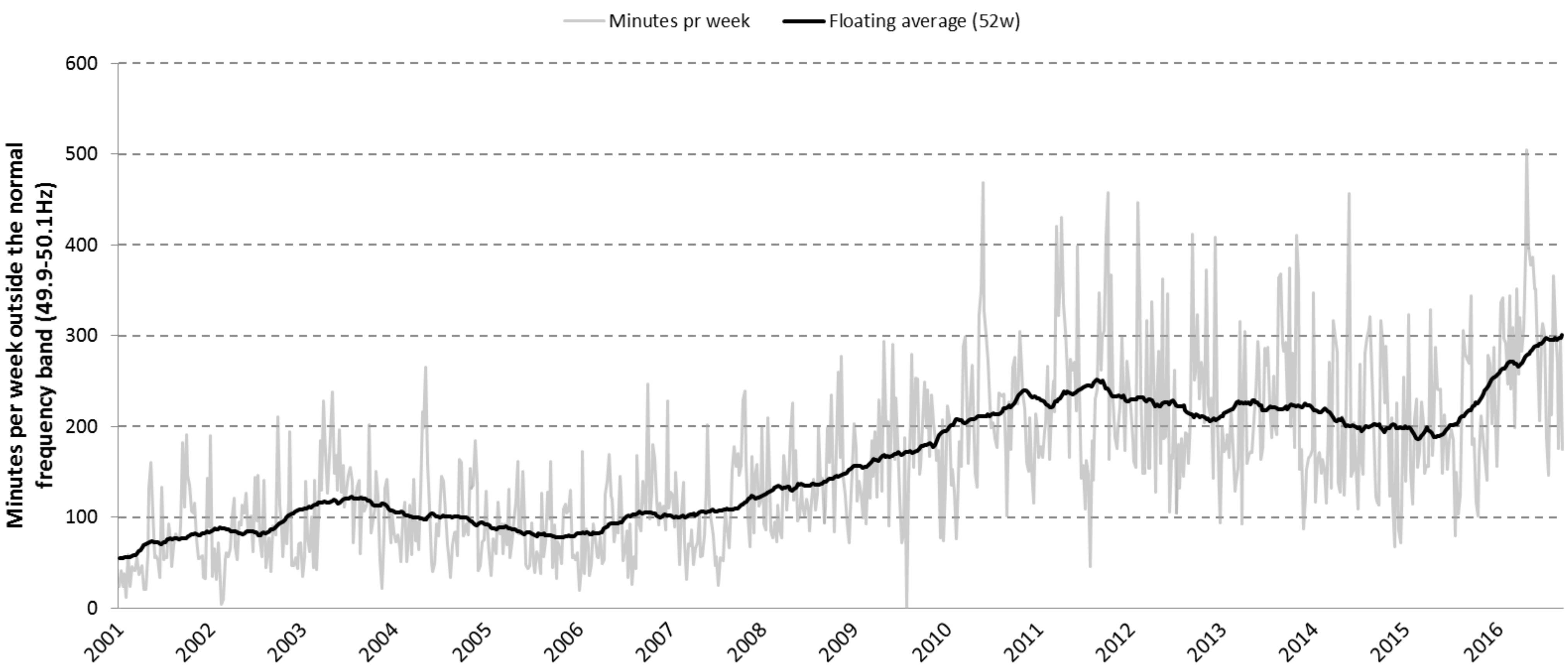
- In physical power markets, the competition with electricity energy volumes is severe which has kept the prices relatively low in Nord Pool area during recent years
- The consumption order of energy sources depends on their production costs meaning that the cheapest forms are used first and then moved to more expensive ones until the energy need is fulfilled [as seen on the right, (*Partanen, 2016*)]
- Because the price volatility isn't sufficiently big enough in physical market, a battery system isn't economically viable in charging with low price and discharging with higher price [as seen on the price diagram of 2016 (*Nord Pool, 2017*)]
- As huge energy volume transmissions are normally required in this market, the limited size of energy capacities set clear restrictions for batteries to be functional enough
- Combined with challenges to predict future price scenarios, **expensive batteries doesn't seem to be profitable in physical markets at the moment**





The development of frequency quality in the grid

- The quality of frequency in the Nordic power system has been decreasing during the last years
- The impact of renewable's increase and the decrease in flexible power can be seen from the diagram (Fingrid, 2017)



Battery suitability for reserve markets

- Generally, it can be stated that the more demanding the operation requirements are, the less there are reserve units capable of realizing them
  - Consequently, the achieved monetary compensations are normally higher for a producer if those strict demands can be fulfilled
  - As battery technology enables short activation times, effective reactions for frequency variations and good efficiency, batteries are well suited for the most demanding operations in the reserve markets
- Therefore, the Frequency Containment Reserves (FCR), where the reserve units have to quickly adapt to frequency shifts, are considered as the most suitable electricity markets for batteries
- The payment is relative to the sold power capacity (€/MW) which is more suitable for batteries than restricting energy prices of physical markets (€/MWh)
- At this moment in Finland, the absolutely biggest share in FCR-N and FCR-D markets is produced by hydropower

Battery capacity should be traded primarily in FCR-N market but FCR-D market also possible

Biggest electrical battery in Nordic countries: Batcave

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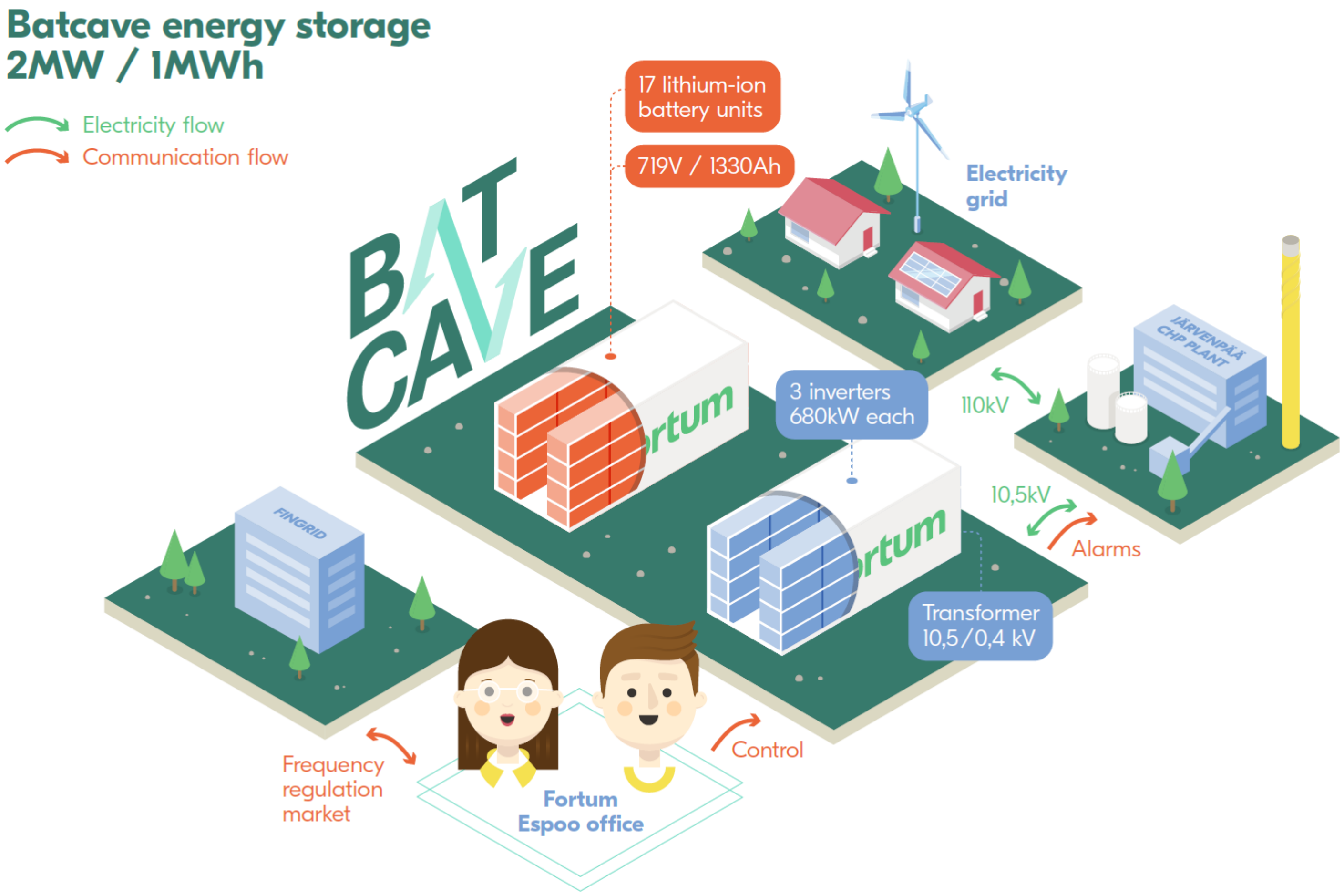
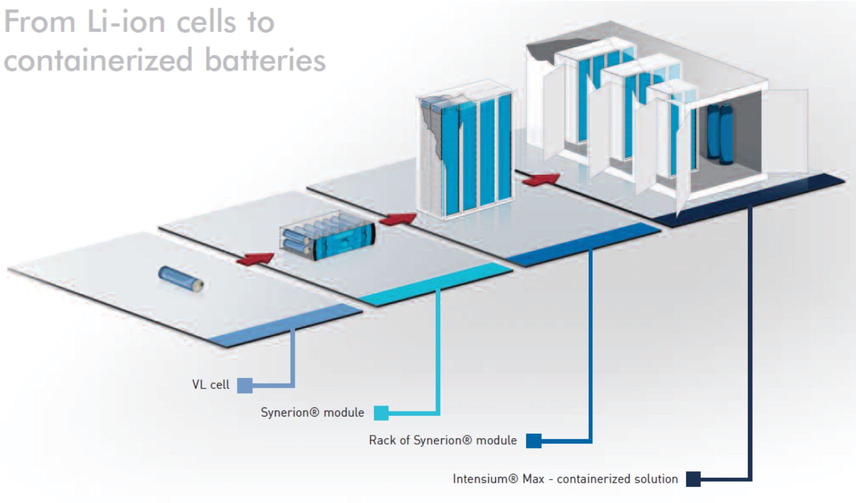
Batcave project details

- Project started in April 2016 and battery was implemented on March 1st 2017
- R&D project for grid balancing
- Biggest electrical battery in Nordic countries
- Installed in Järvenpää power plant
- Operation and trading conducted from Keilalampi
- The investment cost of the Batcave project is around 1,6 million euros and the Finnish Ministry of Employment and the Economy (TEM) granted financial support of 30 % for it



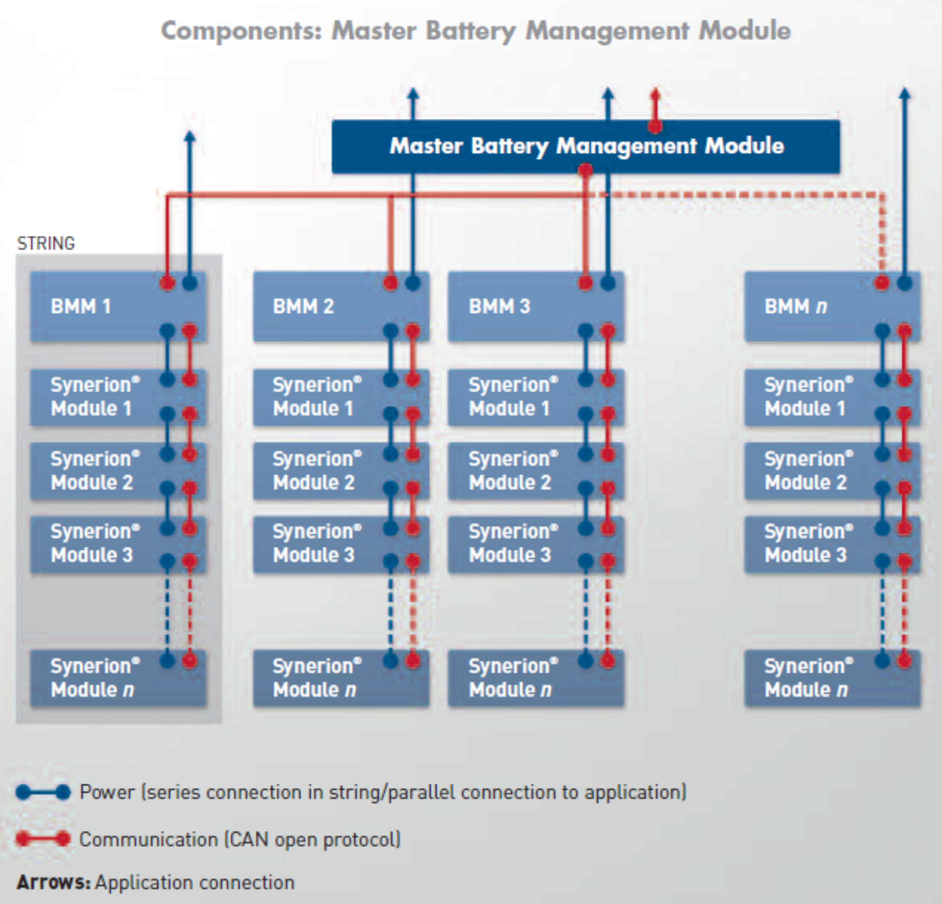
Batcave technology

- The battery was manufactured by Saft in Bordeaux, France
- The battery is a lithium ion type battery with energy capacity of 1 MWh and maximal power capacity of 2 MW
- The lithium ion cells of the battery have positive electrodes with lithiated metal oxides ($LiMO_2$) and the negative electrodes are manufactured from carbon material
- The battery is situated inside a container that is 6 m long, 2,3 m width and 2,4m high
- The container includes 17 energy storage system strings connected in parallel and assembled in racks
  - Every system string include 14 modules and there are 28 lithium ion cells inside every module
- The power conversion system is placed inside another container and it is located next to the battery container.



Batcave communication

- Each module of Batcave battery has its own safety monitoring unit that balances the internal cells and supervises their voltage and temperature values
- Individual modules are connected in series which is called as battery management module (BMM)
  - BMM manages all the modules inside the system string rack with voltage, temperature, current and alarms
  - BMM manages the maximum currents that are authorized during the processes and safely disconnects the system string in case of danger
- All the BMMs are connected to the higher communication system: master battery management module (MBMM)
  - The MBMM calculator is in charge of gathering data and delivering key information to the Fortum's operation desk, including state of charge (SOC), state of health (SOH) and available power



Battery operation benefits with hydropower

- **Batcave battery is utilized in the FCR-N market simultaneously with other Fortum hydropower**
  - This enables the most profitable operation logic
- While using the battery in the same market portfolio as other hydropower it creates an advantage that no other company can offer:
  - If battery is either empty or full and it can't fulfill the grid requirements, the battery owner has to pay a fee to Fingrid that is twice the price that could have been obtained from that hour
  - With Fortum's hydropower portfolio if the battery reaches either empty or full state, then the available hydropower will generate the needed backup power in order to fulfill the grid requirements
    - This enables that the battery can create value around the clock, 24/7
    - This mitigates operation risks and market uncertainty

Real Batcave operation data in July 2017

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What is the future of energy storage systems?

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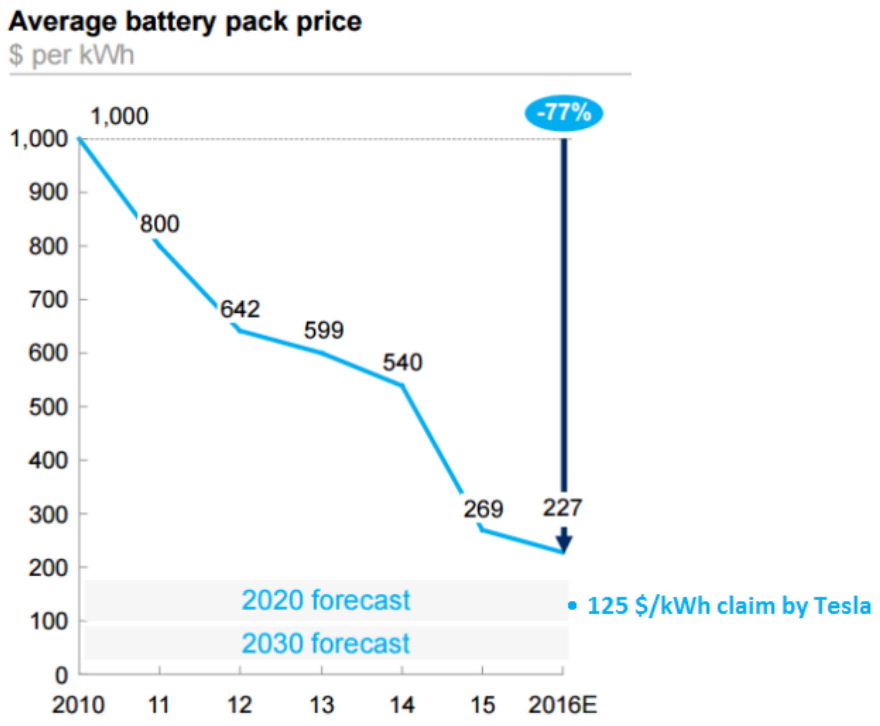
Decrease in battery manufacturing costs

- In order for the battery storage systems to be profitable enough for reserve markets, the manufacturing costs have to decrease sufficiently
- It can be stated that the traditional and expensive battery manufacturing for industrial use has developed slowly during the last century when compared to the other electronic appliances
- The development of Li-ion batteries for electric vehicles and commercial electronics has boosted its major storage characteristics
  - A massive manufacturing process of electric vehicles can offer the needed economy of scale that will decrease the high costs of battery production
- Consequently, there has been a significant fall-off in battery costs during recent years
  - In six years the electric vehicle battery cost have dropped dramatically with 77 % (*McKinsey & Company, 2017*)
  - Tesla claims a new record low price for Li-ion batteries: 125 $/kWh in their newest Gigafactory at Nevada (*Electrek, 2017*)



Market availability for battery storage systems?

- Consequently, it seems quite likely that the battery prices keep on falling in the future
- Nevertheless, as the market share of power capacity in reserve markets is generally relatively small, a large-scale "battery rush" on that market could cause some saturation effects
  - That's why constant examinations on long-term market developments have to be conducted in order to evaluate the profitability prospects in a single market or stacking value with other services
- As compared to traditional power plant projects that require long construction periods, battery storage systems can be built relatively fast
  - **This means that if there is a clear market space for battery projects it's highly probable that those opportunities are rapidly exploited**
  - Example 1: in Germany the capacity based PCR market is covered already with 26 % of battery storage systems with the size of over 250 MW. The prices decrease constantly which creates a challenging situation for old and new installations (*Kivipelto, 2017*)
  - Example 2: there was a massive rush for newly found Enhanced electricity market in UK in 2016, as for the 200 MW size auction there were over 1 200 MW worth of bids which decreased the prices extremely low and thus making the projects not especially profitable (*Steel, 2017*)

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The time scale of batteries in grid balancing

- Currently batteries work well in reserve markets where instant power effects to the grid are required for relatively short time intervals
- However, because battery technology is still expensive and has quite restrictive energy capacity sizes they don't suite well in huge energy volume transmission requirements
  - This means that as solar and wind energy increase their share in the energy mix, batteries cannot compensate alone the production uncertainty of renewables with current energy price levels
- Currently and in the long run, hydropower offers the best and environment friendly energy storage possibility for long term flexibility and seasonal balancing
  - For example to compare: the power output of Oulujoki hydropower plants could be compensated with approximately 200 Batcave batteries
  - However, to compensate the energy volume of flowing water through the turbines and its electricity generation, 500 000 Batcave batteries should be needed
- Thus, hydropower, backed up with battery storage systems, offer the widest time scale horizon – from seconds to months - for balancing the grid and enabling the penetration of renewables in Nordic countries

spring by Fortum

building a virtual battery together with customers

Join the change

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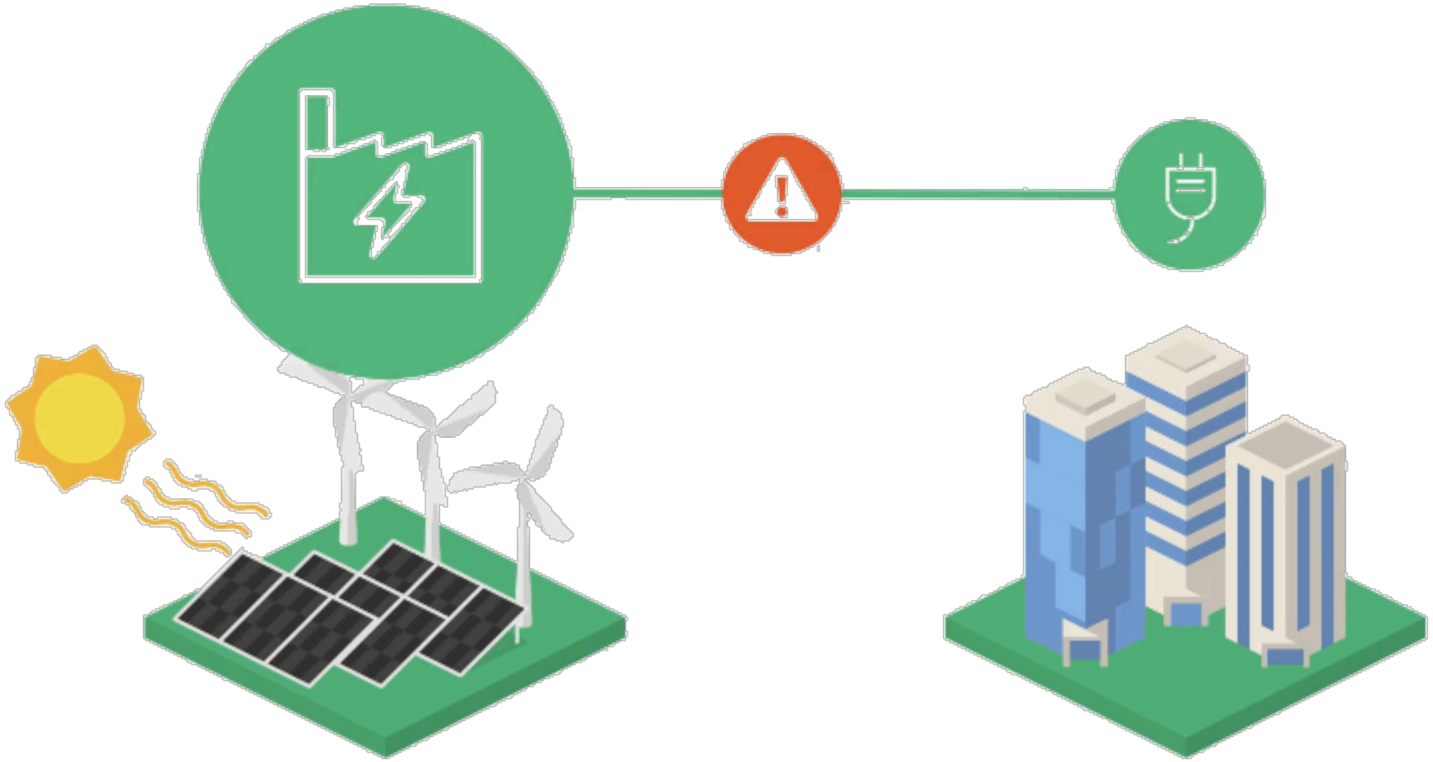
The power industry is facing a revolution - Customers are the solution

Increasing renewables need balancing, storages



Customers already have the needed assets for balancing

Internet is the Smart Grid
Connecting customers is the Uber of the industry

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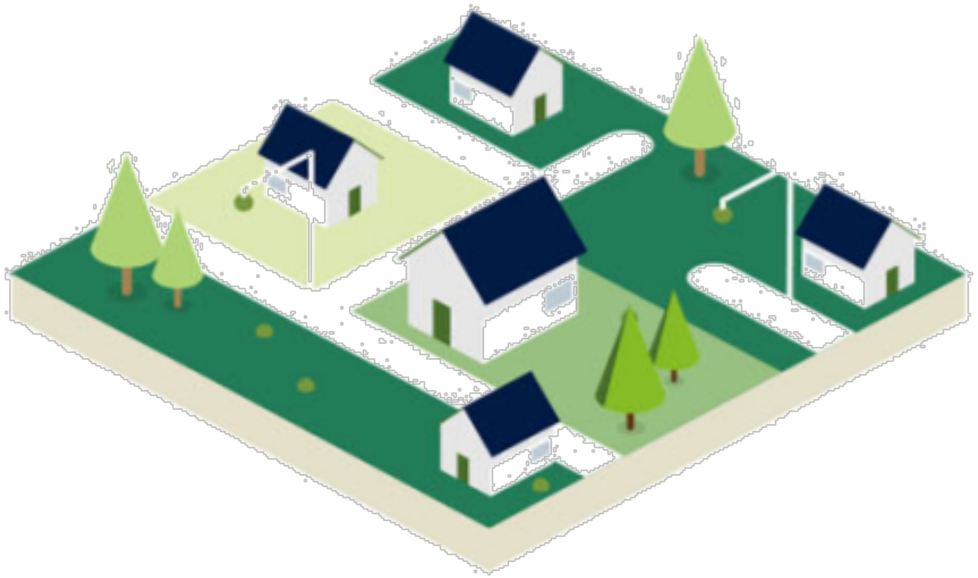
Spring is focusing on two customer segments

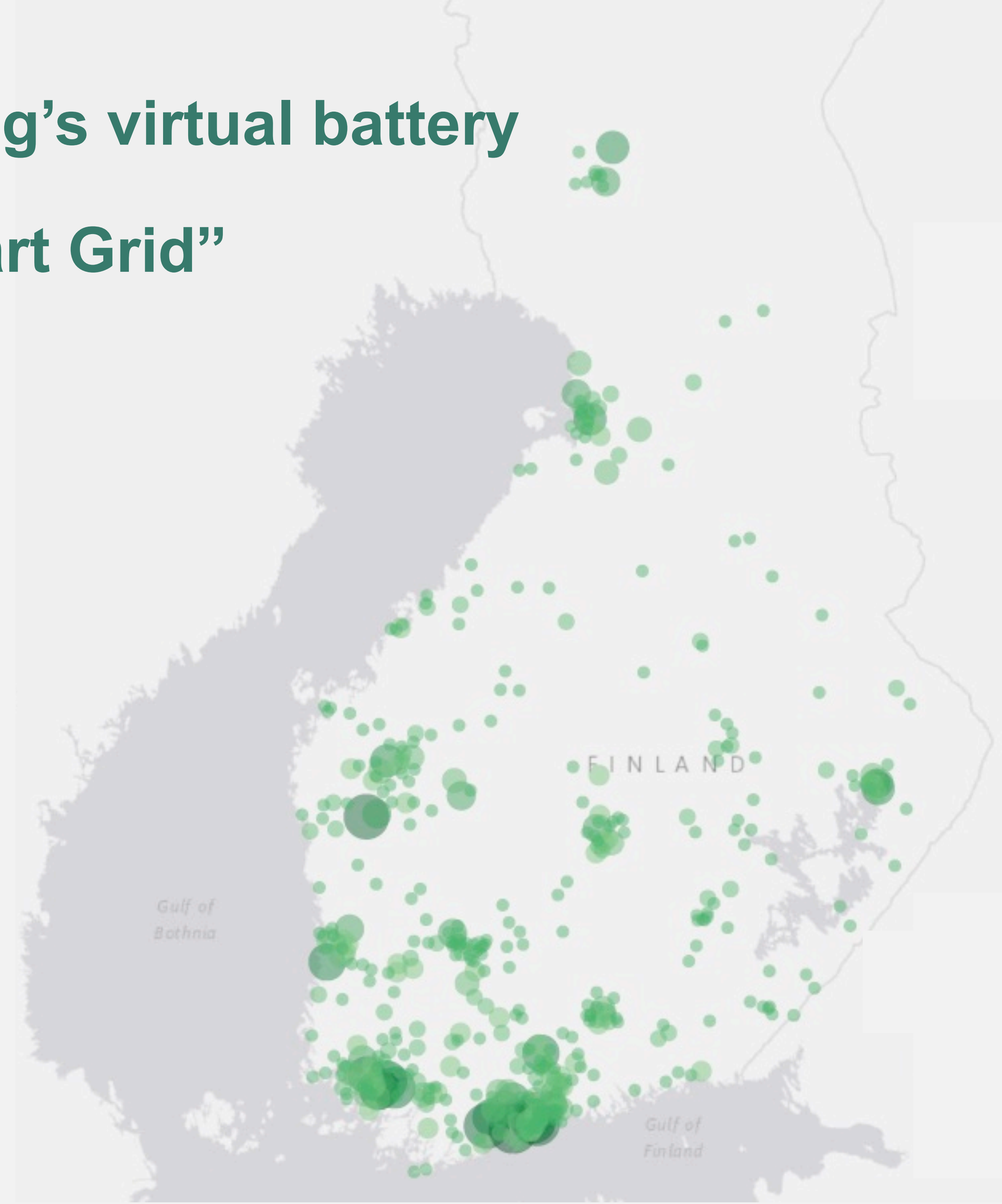
Homes
Flexibility from electric water heaters



Data centers
Flexibility from UPS backup batteries

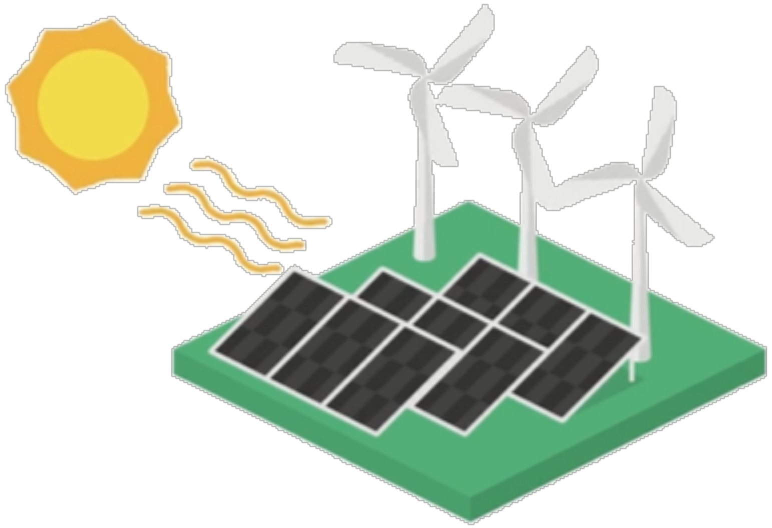
This is Spring’s virtual battery

This is “Smart Grid”



Spring brings value to the customers and to the system

Spring offers customers an effortless way to earn money and fight climate change

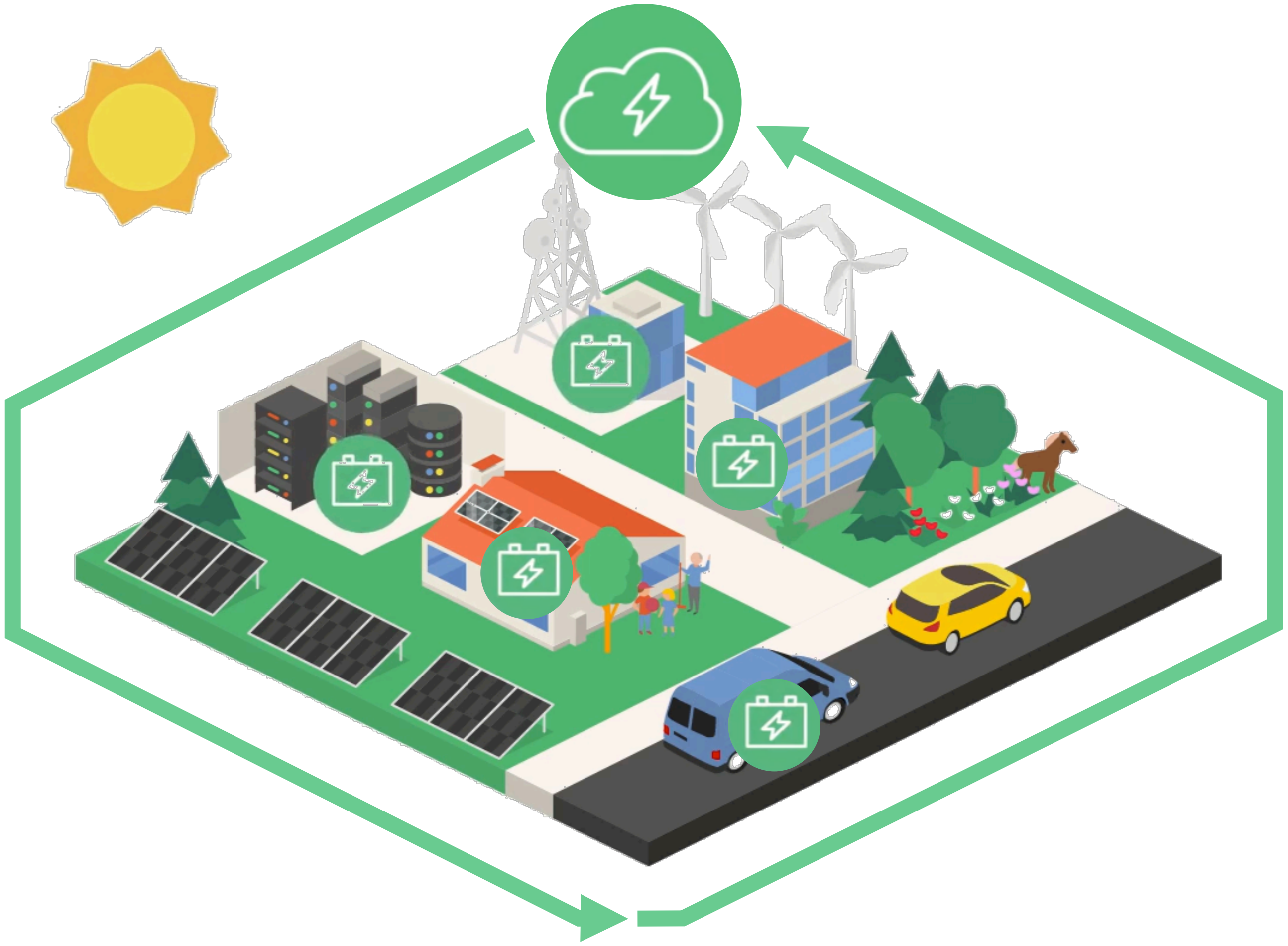


Spring offers the power industry the solution to keep the system in balance

Spring forms a virtual battery from distributed customer assets

Rules of the power system are strict and precise

And only getting stricter



Customer's asset and their use is uncertain and difficult to forecast

Spring is now delivering to customers

1000 homes

Ericsson data center

New Swedish pilot

Pilot: 1st homes in real time market in Europe (in Finland)

Pilot: 1st homes in Swedish real time market

Home and Data Center offerings launched in Finland

2016

2017

2018

Software development

Pilot development

Hardware development

Sales ramp-up

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Thank you!

Questions?
Ask now or contact us later

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